MAINTAINING FIRE-ASSOCIATED BIRD SPECIES ACROSS FOREST LANDSCAPES IN THE NORTHERN ROCKIES

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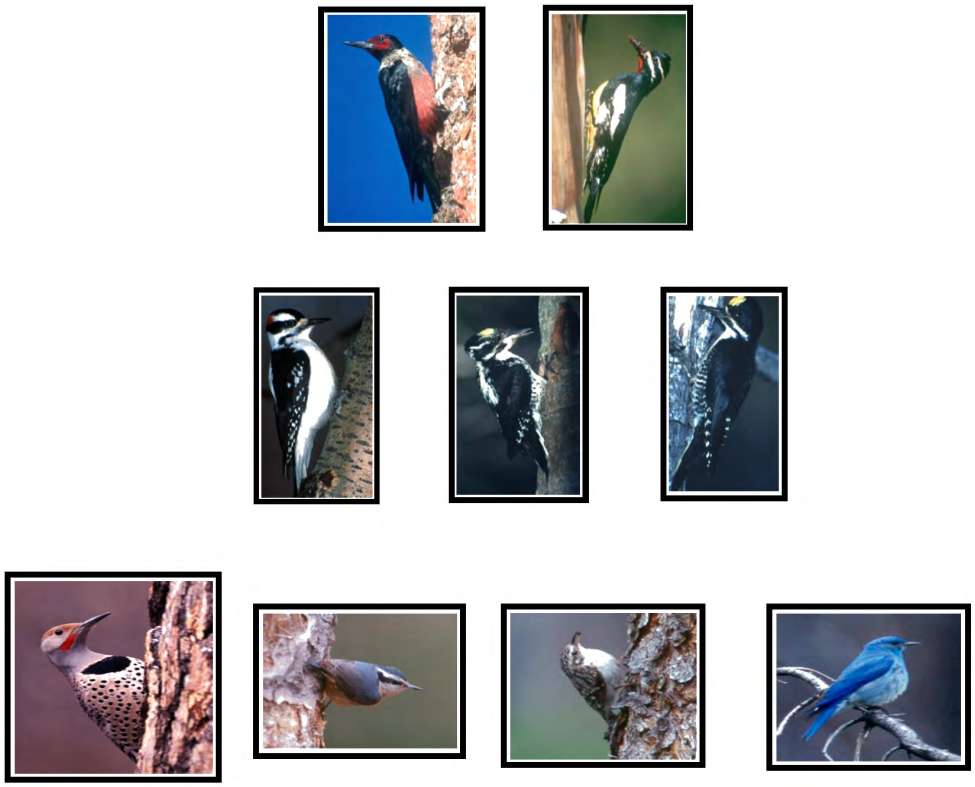

Sallie Hejl and Mary McFadzen
US Forest Service
RMRS - Forestry Sciences Lab
PO Box 8089
Missoula, MT 59807

Thomas Martin
Cooperative Wildlife Research Unit
University of Montana
Missoula, MT 59812

INTRODUCTION

Forest fires are an important natural disturbance process in northern Rocky Mountain forests (Arno 1980, Habeck 1987). Forest fire suppression efforts in the past 70 years, however, have abated this disturbance process and consequently, created one of the potentially most ecologically detrimental human-induced changes in Rocky Mountain forests (Hejl 1994). Exclusion of fire from forests, combined with the salvage logging of the accessible acres that have burned, have prompted concern for fire-associated bird species in the northern Rocky Mountains. Fifteen bird species (woodpeckers, flycatchers and seed-eaters) are generally more abundant in early post-fire forests than in any other major cover type occurring the northern Rocky Mountains (Hutto 1995). Post-fire forests provide suitable and abundant foraging and nesting habitat for these 15 species. Studies have indicated that salvage logging decreases the suitability of post-fire forests for some bird species (Caton 1996, Hitchox 1996, Saab and Dudley 1997). Therefore, in 1997, we initiated a study to examine the effects of salvage logging of burned forests on primary and secondary cavity-nesting birds in Montana and Idaho. Of primary concern are two species, the black-backed woodpecker (a USFS sensitive species) and the three-toed woodpecker, which may be particularly adversely affected by salvage logging (see Table 2 for scientific names of bird species).

To assess the effects of post-fire salvage logging on cavity-nesting birds we examined occupancy of logged and unlogged conditions, nest-site selection, and nesting success at the plot and landscape levels.

STUDY AREA

We conducted the research at 4 post-fire study sites in mixed coniferous forests, which were burned by stand replacement fires in the northern Rocky Mountains near Missoula, Montana. Limited availability of post-fire forests to study constrained us to use sites that were segregated temporally (year burned) and spatially (latitude and longitude; Table 1). Three sites, Chamberlain Creek, Henry Peak, and Ward Mtn., which burned in 1994, were subsequently salvage logged. The fourth study site, Warrior's Face, which was located in the Selway-Bitterroot and Frank Church River of No Return Wilderness Areas, Idaho, burned in 1996 and was not salvage logged. Within the perimeters of each burn, we selected a core area burned by moderate to high-intensity crown fire for study (Table 1). The areas outside these cores were primarily low intensity underburns or not feasible to study. Salvage logging prescriptions with snag retention requirements were designed and implemented by land managers prior to initiation of the study (Table 1). Total area salvage logged varied by study site and ranged from 21-73% (Table 1). Pre-fire tree species composition of mixed-conifer forests differed slightly among study sites, however, most tree species occurred on all sites (Table 1). Within study sites, pre-fire tree species composition was inherently variable due to elevation gradient and slope aspect. All 4 study sites were surveyed each breeding season from 1997-99 except for Ward Mtn., which was not covered in 1999 due to logistical constraints.

METHODS

Nest Searching, Monitoring, and Mortality

In 1997-99, from early May through July, we surveyed for 9 cavity-nesting bird species (see Table 2 for common and scientific names) by walking established variable-width transects placed 200 m apart (Saab and Dudley 1998). Every 100 m we stopped for 5 min to listen for birds. At any point along the transect, birds detected visually or aurally were immediately followed. Once a nest was found it was monitored every 3-4 days until the nest fledged young or failed (Martin et al. 1997). A video-board camera on a telescoping pole (Proudfoot 1996) allowed us to view contents of some nests. Direct observation of adult behavior was used to determine status and breeding stage for nests we were unable to view with the camera.

Nests were determined successful if nestlings survived to near fledging age. We assigned failed nests to the following mortality causes: *predation*, clutch or brood missing prematurely (via visual inspection) or other evidence indicating predation; *weather induced*, nestlings dead in nest (1998 only); and *unknown*, nest failed prematurely but unable to confirm contents missing.

Microhabitat Sampling

We sampled vegetation within a circular plot of 11.3 m radius (0.04 ha) around nests and within systematically placed plots to compare used (*nest plot*) to available microhabitat (*systematic plot*). Microhabitat plots were defined as follows: *nest plot* - centered around a nest tree; and *systematic plot* - centered at points placed 200 m apart along bird survey transects which covered the entirety of each study site.

Microhabitat characteristics were measured within nest and systematic plots following procedures by Martin et al. (1997) and Saab and Dudley (1998) with some modifications. For all trees ≥8 cm diameter at breast height (dbh), we recorded the dbh, species, tree condition (live or dead [snag]) and top condition (intact or broken [broken before the fire or broken after the fire]). Within a 5-m radius from the plot center, we estimated the percent of ground covered with downed wood >12 cm diameter. Canopy cover was measured with a densiometer in 4 quads of the 5-m radius plot and averaged for percent cover. We measured nest-tree height and nest height using a clinometer. We defined nest and systematic plots as *logged* or *unlogged* according to the presence or absence of cut stumps.

Statistical Analysis

We examined nest-site selection by analyzing microhabitat variables at the *landscape level* and the *plot level*. For species with large enough sample sizes, we employed backwards stepwise multiple logistic regression to identify which variables best differentiated nest plots from systematic plots at the landscape level. Two models were created to determine if species used microhabitat differently within logged and unlogged landscapes: *logged landscape level* - the 3 logged study sites pooled; and *unlogged landscape level* - the unlogged study site.

At the plot level, we used Mann-Whitney *U*-tests to compare means of continuous microhabitat variables of nest plots to means of unlogged systematic plots and logged systematic plots, across all study sites. We also randomly selected 1 tree >15 cm dbh (which was the smallest dbh of all nest trees) per systematic plot and compared its top

condition and dbh to that of nest trees. Because we conducted 7 simultaneous univariate tests of microhabitat variables per species and treatment, we applied a Bonferroni adjustment (% = 0.05, $P < 0.007$). A preference index was created to determine if cavity nesters as group selected specific tree species for nesting. We converted the number of each tree species used and available to percentages, and then subtracted the percentage available from the percentage used per study site. A positive index value indicates use and a negative value indicates avoidance.

Hierarchical cluster analysis was used to determine similarity of nest microhabitat characteristics among the 9 cavity-nesting species. We transformed mean values of microhabitat variables using standardized z-scores and calculated squared Euclidean distances.

Following Martin et al. (1997), we calculated values used to estimate Mayfield daily nest survival rates and nest success (egg laying through nestling stages; Mayfield 1961, Mayfield 1975, Hensler and Nichols 1981). The program CONTRAST (Hines and Sauer 1989) was used for statistical comparisons of Mayfield daily survival rates. We made statistical comparisons at the *plot* (nests in unlogged plots vs. nests in logged plots) and *landscape* (nests in the unlogged study site vs. nests in the three logged study sites pooled) levels only for species with ≥20 nests per treatment, the recommended sample size for calculating Mayfield rates (Hensler and Nichols 1981). For species with <20 nests, we only calculated and report Mayfield nest success estimates.

RESULTS AND DISCUSSION

Occupancy of Post-fire Forests

Combining all study sites we found and monitored 464 nests of 9 species (Table 2). Most cavity-nesting bird species were found on all 4 study sites except for Williamson's sapsucker, Lewis's woodpecker, and brown creeper (Table 2). The nest density estimate for cavity nesters as a group in the unlogged study site more than double the second year post-fire (Table 3). Only for the third year post-fire could we compare time since burn across all study sites. Nest density estimates were similar between Warriors' Face, the unlogged study site (0.23/ha), and Ward Mtn., a salvage logged study site (0.22/ha). Both of these estimates were slightly higher than the other 2 logged sites (Table 3). Mean nest density for all logged sites combined for the third year post-fire was 0.185 ± 0.03 SE.

The frequency at which cavity nesters placed their nests in unlogged vs. salvaged-logged conditions was examined at two spatial levels. At the nest plot level (combining nests across all study sites), occupancy of plots formed 3 distinct groups: species with nests mostly in unlogged plots, species with nests divided almost equally in both plots, and species with nests primarily in logged plots. This same pattern of occupancy also was evident at the logged landscape level (the 3 logged study sites combined). At both the plot and logged landscapes levels occupancy of conditions was generally consistent among species. For example, the brown creeper, black-backed and three-toed woodpeckers almost exclusively occupied unlogged conditions at both levels (Fig. 1). In contrast, the red-breasted nuthatch, Lewis's woodpecker, and Williamson's sapsucker nested most frequently in logged conditions (Fig. 1). These 3 species did not occur or

occurred in very low numbers within the unlogged landscape (Warrior's Face study site; Fig. 1B). Hairy woodpeckers, mountain bluebirds, and northern flickers occupied both logged and unlogged conditions at both levels (Fig. 1). Although the total area surveyed in the logged landscapes was twice that of the unlogged landscape (Table 1), the number of three-toed woodpecker and black-backed nests was highest in the unlogged landscape (Fig. 1B).

Selection and Use of Microhabitat

Plot level.--Cluster analysis of microhabitat variables illustrated that nest sites differed among cavity-nesting species. For example, nest sites of Lewis's woodpeckers were unique in relation to the other 8 species (Fig. 2). Black-backed, three-toed, and hairy woodpeckers shared similar nest-site characteristics, and as did northern flickers and mountain bluebirds (Fig. 2).

Examination of microhabitat at the plot level emphasizes the differences in use among cavity-nesting species and also species-specific selection of certain characteristics within post-fire forests. Five of 7 species selected areas for nesting with higher snag densities when compared to logged systematic plots (Table 4). In contrast, 2 species had nest sites with similar snag densities to logged plots but significantly lower densities than unlogged plots. Nest trees of all species were larger than those available in both treatments. Williamson's sapsucker and red-breasted nuthatches had more live trees within nest plots than other species. Treatments differed significantly from each other in snag density, overstory cover, and treetop condition (Table 4).

Landscape Level.--Examination of microhabitat at the landscape level with multiple logistic regression provided explanation of selection for some cavity-nesting

species. The percent of nests correctly classified was >70% in unlogged and logged landscapes for northern flickers and mountain bluebirds (Table 5). Important characteristics of both species across treatments included large (>40 cm dbh) nest trees with broken tops (Table 5). Flickers and bluebirds also generally avoided areas of live trees within the burns. In logged landscapes, bluebird nests were strongly associated with higher snag densities. Models also were created for hairy, three-toed and black-backed woodpeckers but nest classification was poor (<50%).

Although there was no preference by bird species for nest tree species, cavity nesters as a group showed preference for nest tree species within study sites (Fig. 3). At the unlogged study site where Douglas-fir and lodgepole pine occurred in equal proportions, cavity nesters showed a strong preference for Douglas-fir (Fig. 3). In contrast, at a logged study site, cavity nesters avoided Douglas-fir and selected for ponderosa pine and western larch, which comprised only 12% of available trees (Fig. 3).

Nest Fate

Of 460 nests for which we were able to determine fate, 25% (n = 117) failed prior to fledging young. The proportion of nest failures and successes was similar between unlogged and logged conditions at both the plot (log-likelihood ratio test, G_1 = 2.92, P = 0.087) and landscape levels (G_1 = 1.8, P = 0.179). Overall (all nests combined per species) Mayfield nest success for all cavity nesters ranged from 57-91% (Table 6). Samples sizes were sufficient for comparing Mayfield daily survival rates between treatments at the plot and landscape levels for only three species. Daily survival rates were lower in logged vs. unlogged conditions for hairy woodpeckers at the plot level and for mountain bluebirds at the landscape level (Table 6). Northern flickers had slightly

higher rates in logged conditions at both levels but not statistically different than unlogged conditions (Table 6).

We classified 117 failed nests into the following mortality causes: 57% predation, 45% unknown, and 6% weather induced. Because we were unable to see into many nests to verify contents, predation and weather-influenced mortalities likely were underestimated. Observations of predatory events were rare. In logged conditions, Yellow-pine chipmunks (*Tamias amoenus*) were common and were responsible for eating eggs in 2 nests. At a third nest, a sharp-shinned hawk (*Accipiter striatus*) was observed perching at a cavity of which nestlings were subsequently found missing. In unlogged conditions, a red squirrel (*Tamiasciurus hudsonicus*) was observed being chased by adult birds of a recently depredated nest that contained eggs. Several failed nests showed signs of black bear (*Ursus americanus*) predation.

Periods of cold, wet weather had a negative effect on mountain bluebird nestling survival in 1998. Of the 16 nests that we could see into in 1998, 44% (n = 7 nests) contained dead nestlings. In 1999, 7% (n = 1 nest) of 14 viewable nests contained dead nestlings. We excluded 1997 data from this comparison because we only had limited nest-viewing equipment and only 2 failed nests were viewable. Mountain bluebird nest success estimate was lower in 1998 (49%) than in 1997 (64%) and 1999 (64%) but daily nest survival was not significantly different (CONTRAST, $X^2_2 = 2.18$, $P = 0.335$). We believe the wet cold weather during the early nestling stage decreased insect availability and thus, adults were incapable of securing prey to adequately provision nestlings (Power and Lombardo 1996).

STATUS OF RESEARCH

Currently we are writing manuscripts for submission to scientific journals. Analysis of foraging data can be found in the Final Report for INT-97041-RJVA.

ACKNOWLEDGMENTS

This research was supported in part by funds provided by the Rocky Mountain Research Station, Forest Service, US Department of Agriculture. Additional support was provided by the Montana Cooperative Research Unit/University of Montana, and the US Fish and Wildlife Service (Regions 1 and 6). We also thank the following agencies and individuals for their contribution to this study: 1997-99 field assistants, Bitterroot National Forest, Bureau of Land Management, Crown-Pacific, Mr. and Mrs. Baxter, Lolo National Forest, Montana Department of Fish, Wildlife and Parks, Karen Newlon, Hugh Powell, Doug Booth, Stacey Clark, Jon Dudley, and Vicki Saab. Rudy King and Dave Turner of the Rocky Mountain Research Station provided helpful statistical advice.

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Table 1. Characteristics of 4 post-fire study sites of the northern Rocky Mountains, 1997-99.

Study site Latitude, longitude Mean elevation	Year burned	Area burned	Area of burn studied (ha)			Snag retention (snags/0.40 ha)	Pre-fire tree species	
			not logged	salvage logged	total		Dominant	Other[a]
Chamberlain Ck. 46°56'N,113°15'W 1844 m	1994	494 ha	154	40	194	all snags < 18 cm dbh	subalpine fir lodgepole pine	2,3,6
Henry Peak 47°26'N,114°46'W 1646 m	1994	3321 ha	93	246	339	9-12 snags >32.5 cm dbh	Douglas-fir ponderosa pine	1,2,4
Ward Mtn. 46°11'N,114°15'W 1875 m	1994	601 ha	72	64	136	2 snags 23-35 cm dbh and 3 snags >35 cm dbh	Douglas-fir ponderosa pine lodgepole pine	1,3
Warrior's Face 45°42'N,114°38'W 1768 m	1996	1334 ha	281	0	281		Douglas-fir lodgepole pine	1,3,5

[a]Other: 1 = subalpine fir (*Abies lasiocarpa*), 2 = western larch (*Larix occidentalis*), 3 = Englemann spruce (*Picea englemannii*), 4 = lodgepole pine (*Pinus contorta*), 5 = ponderosa pine (*Pinus ponderosa*), 6 = Douglas-fir (*Pseudotsuga menziesii*).

Table 2. Number of nests monitored of 9 cavity-nesting species in 4 post-fire study sites of the northern Rocky Mountains, 1997-99.

		Number of nests				
		Unlogged	Logged			
Species	Code	Warrior's Face	Chamberlain Ck.	Henry Peak	Ward Mtn.[a]	Total
Lewis's woodpecker (*Melanerpes lewis*)	LEWO	0	0	12	0	12
Williamson's sapsucker (*Sphyrapicus thyroideus*)	WISA	0	3	3	4	10
Hairy woodpecker (*Picoides villosus*)	HAWO	23	9	18	9	59
Three-toed woodpecker (*Picoides tridactylus*)	TTWO	35	13	6	7	61
Black-backed woodpecker (*Picoides arcticus*)	BBWO	30	6	5	3	44
Northern flicker (*Colaptes auratus*)	NOFL	29	19	39	11	98
Red-breasted nuthatch (*Sitta canadensis*)	RBNU	3	2	7	6	18
Brown creeper (*Certhia americana*)	BRCR	6	12	0	1	19
Mountain bluebird (*Sialia currucoides*)	MOBL	42	39	40	22	143
Total		168	103	130	63	464

[a]study site not used in 1999

Table 3. Nest density estimates by year post-fire of 9 cavity-nesting species surveyed in 4 study sites of the northern Rocky Mountains, 1997-99.

	Number of nests/ha			
	Unlogged	Logged		
Year post-fire	Warrior's Face	Chamberlain Ck.	Henry Peak	Ward Mtn.
1	0.11			
2	0.26			
3	0.23	0.16	0.18	0.22
4		0.19	0.17	0.28
5		0.18	0.12	

Table 4. Microhabitat characteristics of nest plots for 7 cavity-nesting species compared to unlogged and logged systematic plots in post-fire forests of the northern the Rocky Mountains, 1997-99. Superscript 'a' or 'b' indicate significant difference between nest plots and unlogged or logged plots, respectively. Superscript 'c' indicates significant difference between random unlogged and logged plots. Variables were significant at $P < 0.007$ (adjustment with Bonferroni correction for 7 simultaneous tests; Mann-Whitney *U*-test for numerical variables and Chi Square Likelihood Ratio for nest tree top condition.

Species	*n*	Number snags		Mean snag dbh (cm)		Number live trees		Overstory cover (%)		Woody debris (%)		Nest tree dbh (cm)		Nest tree top condition	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	broken (%)	intact (%)
Lewis's woodpecker	12	0.67[a]	0.26	19.5	7.68	0.0	0.0	5.77[a]	1.84	3.10	0.50	61.9[ab]	6.63	75	25[b]
Williamson's sapsucker	10	2.80[a]	0.51	46.3[a]	2.87	3.70[ab]	1.45	27.3	4.96	4.88	1.19	71.3[ab]	9.49	70	30[ab]
Hairy woodpecker	59	6.15[b]	0.55	34.7	1.57	0.19[a]	0.09	23.5[ab]	1.85	4.79	0.74	38.8[ab]	2.21	39	61[a]
Three-toed woodpecker	61	7.15[b]	0.49	33.1	1.22	0.74	.040	30.8[b]	2.14	5.06	0.69	31.1[ab]	1.15	26	74[a]
Black-backed woodpecker	44	7.89[b]	0.67	35.1	1.0	0.0[ab]	0.0	32.3[b]	2.34	4.64	0.87	31.8[ab]	1.10	18	82
Red-breasted nuthatch	18	5.00[b]	0.90	36.6	2.54	2.06	1.15	27.4	4.74	4.59	0.85	35.7[ab]	4.45	89	11[ab]
Brown creeper	19	6.89[b]	0.93	36.8	2.31	0.37	0.37	34.1[b]	3.67	6.57	1.06	46.6[ab]	4.29	10	90
Random															
unlogged	125	6.51[c]	0.38	33.7	0.81	1.45	0.33	30.7[c]	1.39	5.30	0.47	24.9	0.76	7	93[c]
logged	75	2.59[c]	0.36	31.1	2.77	1.13	0.42	16.0[c]	1.68	6.75	0.67	25.7	1.94	22	78[c]

Table 5. Results of stepwise multiple logistic regression of nest and systematic microhabitat plots within unlogged and logged landscapes in post-fire forests of the northern the Rocky Mountains, 1997-99. Variables with coefficient signs indicate presence in final model. Variable means and SE are listed for comparison between treatments.

Model variable	Northern flicker						Mountain bluebird					
	Unlogged landscape 29 nests			Logged landscapes 67 nests			Unlogged landscape 41 nests			Logged landscapes 99 nests		
	sign	$\bar{x}$	SE	sign	$\bar{x}$	SE	sign	$\bar{x}$	SE	sign	$\bar{x}$	SE
Number of snags		5.83	0.85		3.13	0.41		7.57	0.73	+	4.74	0.38
Mean snag dbh (cm)		43.9	2.66	-	27.2	2.16		34.7	1.81		32.0	1.49
Number live trees		0.0	0.0	-	0.18	0.09	-	0.0	0.0	-	0.34	0.13
Overstory cover (%)		26.6	2.58		14.8	1.91		29.4	1.77		19.5	1.45
Woody debris (%)	-	3.12	0.58		7.32	0.86	-	2.27	0.35		7.46	0.69
Nest tree dbh (cm)	+	46.9	3.78	+	48.8	2.32	+	40.9	2.44	+	38.5	1.87
Nest tree top condition (% broken/intact)	+	59/41		+	62/38		+	38/62		+	63/37	
Nests correctly classified (%)		79			73			71			73	

Table 6. Nest success (Mayfield estimates) in unlogged and logged conditions at 2 spatial levels and overall (all nests combined) for 9 cavity-nesting species in post-fire forests of the northern Rocky Mountains, 1997-99. Values in bold indicate species with sufficient sample sizes to statistically test daily survival rates between treatments using program CONTRAST).

	Plot				Landscape					
	Unlogged		Logged		Unlogged		Logged		Overall	
Species	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Lewis's woodpecker			81	12			81	12	81	12
Williamson's sapsucker	40	2	82	8			72	10	72	10
Hairy woodpecker	**96***	**36**	**74***	**23**	**93**	**23**	**83**	**36**	87	59
Three-toed woodpecker	87	50	47	10	**89**	**35**	**71**	**25**	79	60
Black-backed woodpecker	68	39	100	2	68	27	69	41	69	41
Northern flicker	**47**	**49**	**60**	**45**	**43**	**28**	**57**	**66**	53	94
Red-breasted nuthatch	100	7	85	11	100	3	89	15	91	18
Brown creeper	74	18	100	1	100	6	68	13	76	19
Mountain bluebird	**64**	**82**	**49**	**57**	**91****	**40**	**57****	**99**	57	139

**$P \leq 0.05$, *$P \leq 0.10$ (alpha levels for program CONTRAST tests of Mayfield daily survival rates between nests in logged and unlogged conditions by spatial level).

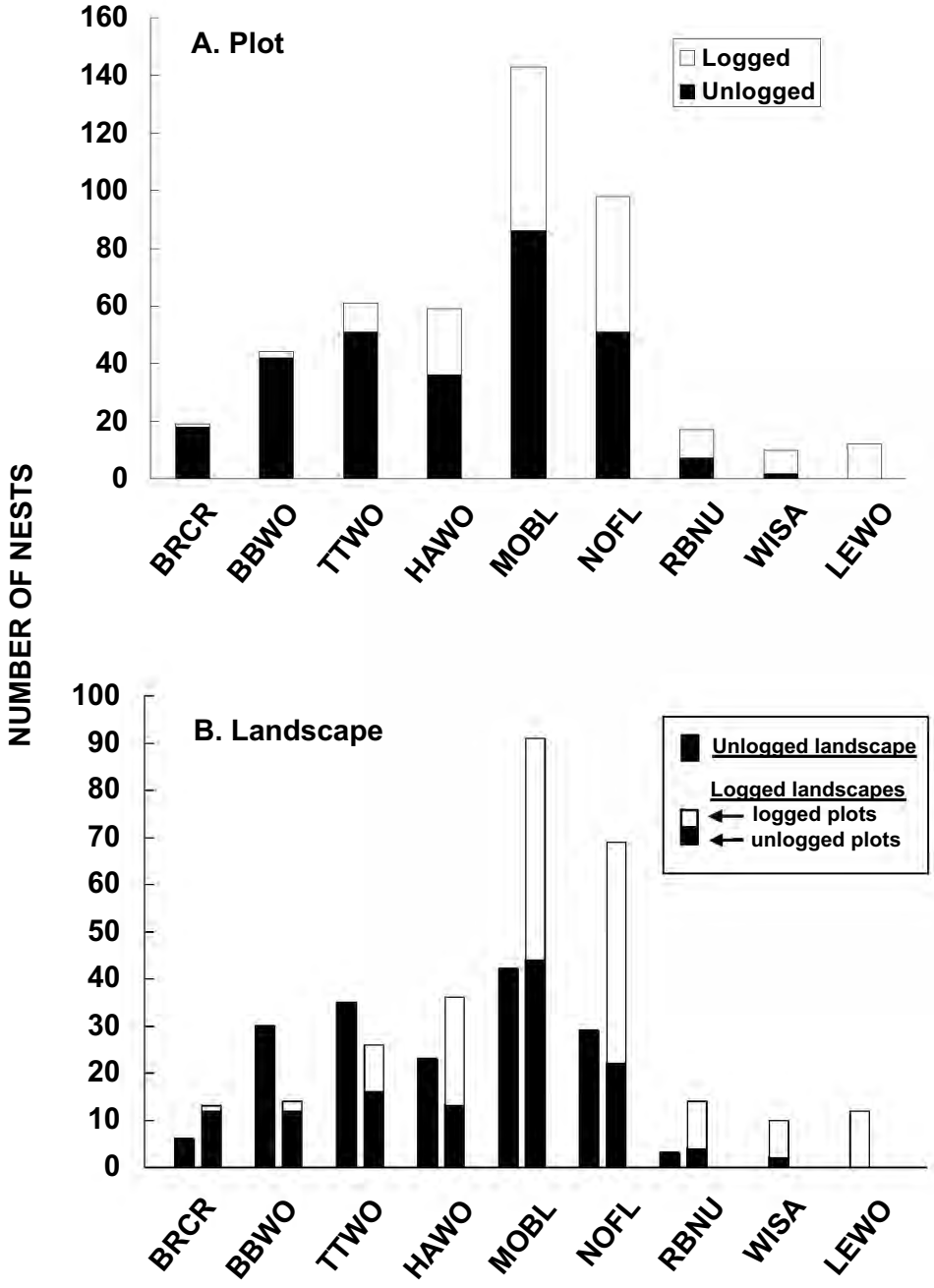

Fig. 1. Number of nests for 9 cavity-nesting species in post-fire unlogged and logged conditions by (A) plot level and (B) landscape level. Species codes are in Table 2.

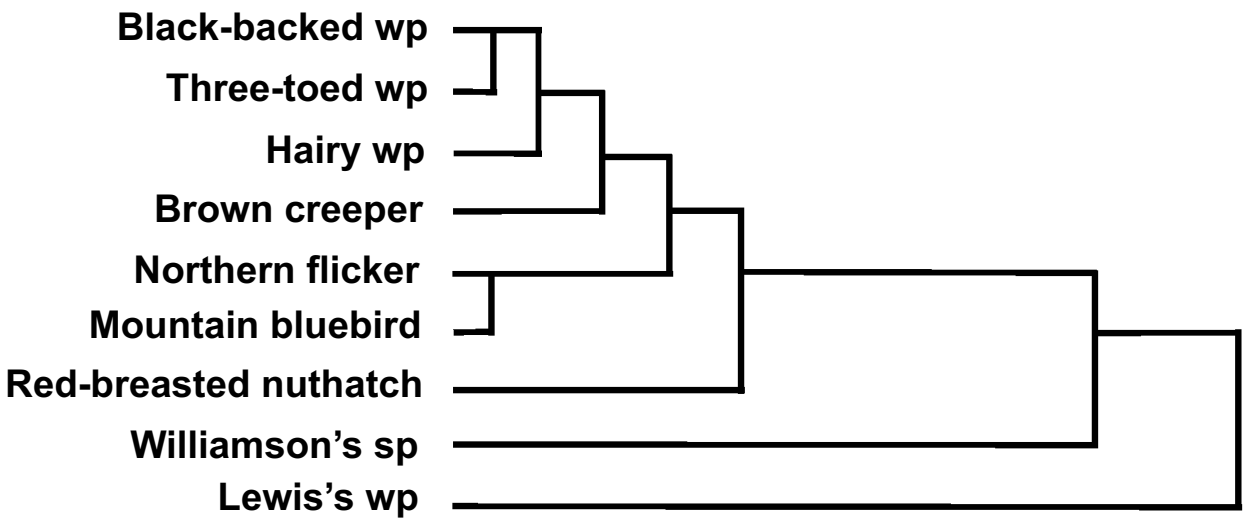

Fig 2. Cluster analysis of cavity-nesting species based on squared Euclidean distances between mean values of 7 microhabitat variables.

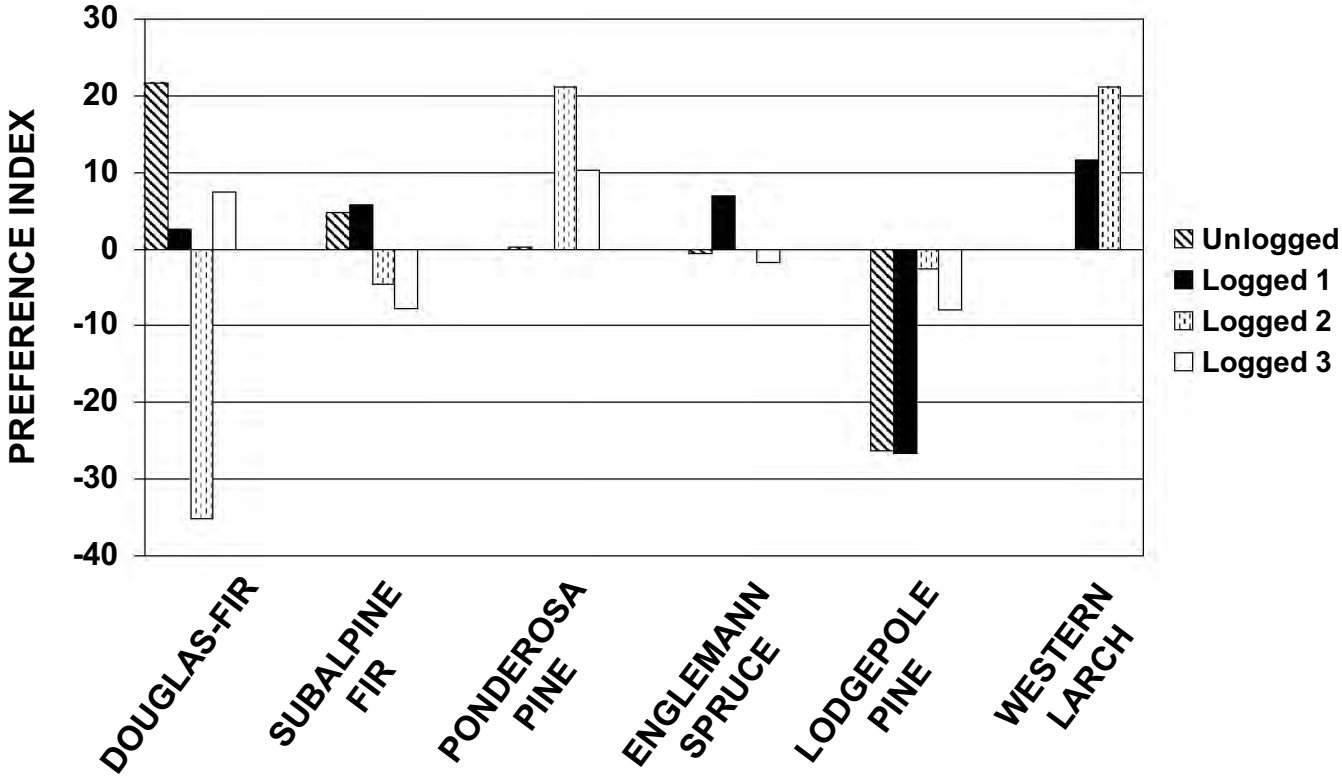

Fig. 3. Preference index (use [all cavity-nesting species combined] minus availability) for nest tree species within the unlogged study site and the 3 logged study sites.